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Teramura et al.

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(54) **SPECTROMETER AND IMAGE FORMING APPARATUS HAVING THE SAME**

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G01J 3/18 (2006.01)
G01J 3/20 (2006.01)
G01J 3/50 (2006.01)

(52) **U.S. Cl.**

CPC ***G01J 3/0205*** (2013.01); ***G01J 3/02*** (2013.01); ***G01J 3/0262*** (2013.01); ***G01J 3/18*** (2013.01); ***G01J 3/20*** (2013.01); ***G01J 3/50*** (2013.01)

(58) **Field of Classification Search**

USPC 356/305, 328, 334
See application file for complete search history.

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(57) **ABSTRACT**

There is provided is a spectrometer having a concave reflection type diffraction element, wherein, among surfaces other than a diffraction surface of the diffraction element, non-diffraction surfaces which are located outside the diffraction surface at the same side as the diffraction surface are a glossy surface, the spectrometer includes a light detection unit which is located at an imaging position of a first-order diffracted light diffracted by the diffraction element to receive the first-order diffracted light, and the light detection unit is disposed inside optical paths of light beams regularly reflected on the non-diffraction surfaces outside the diffraction surface. Accordingly, it is possible to effectively suppress a stray light reflected on the surfaces other the diffraction surface from being incident into the light detection unit and to detect the light spectrally diffracted by the diffraction surface at high accuracy.

13 Claims, 5 Drawing Sheets

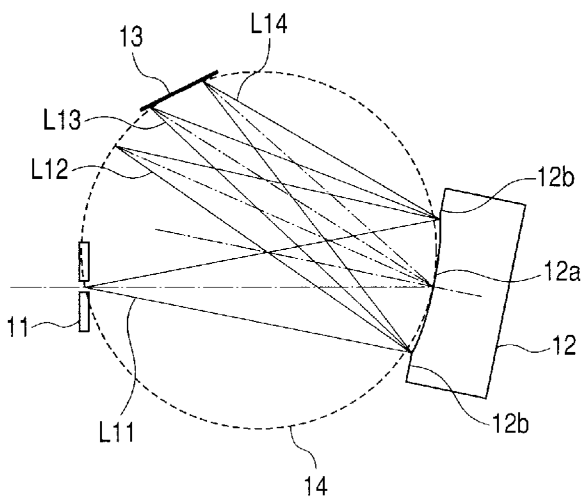

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FIG. 1

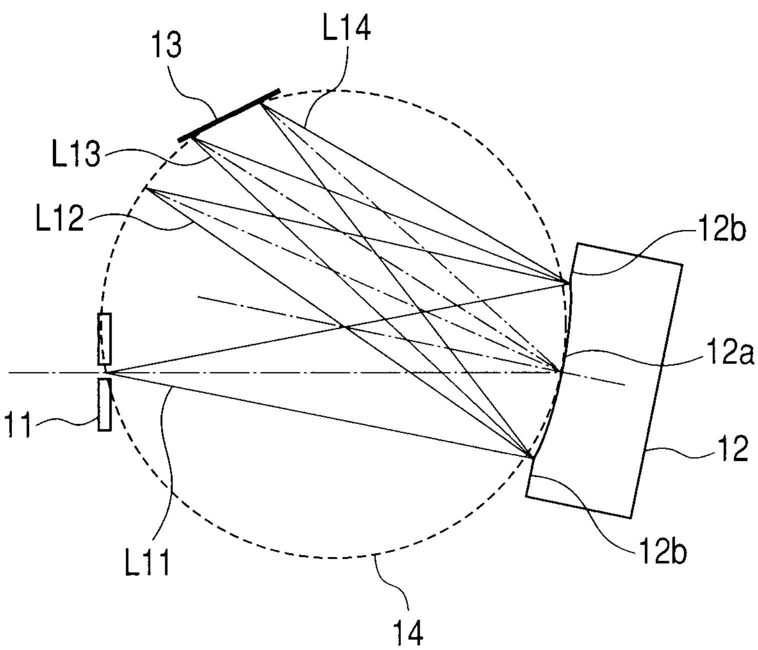

13
L14
L13
L12
12b
12a
11
12
L11
12b
14

FIG. 2

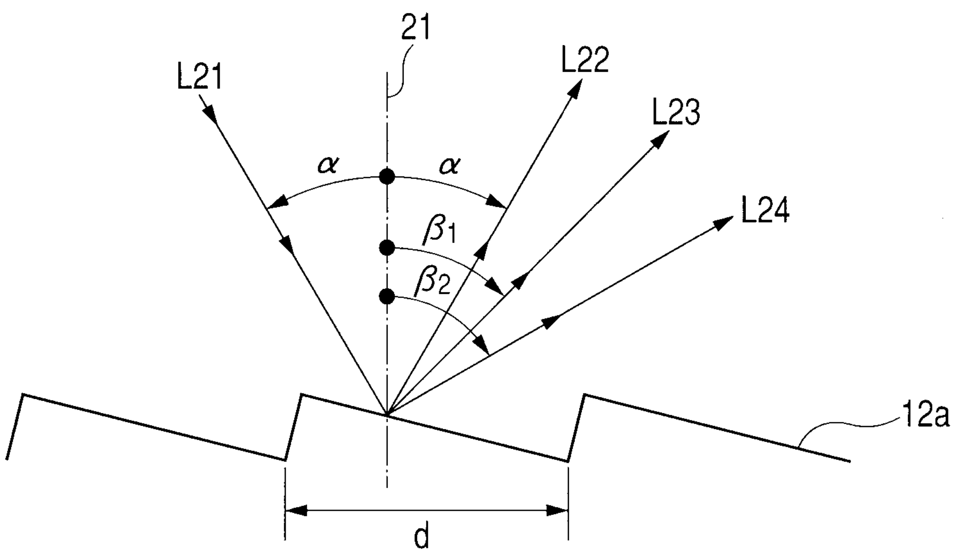

21
L21
L22
L23
L24
α
α
β1
β2
12a
d

FIG. 3

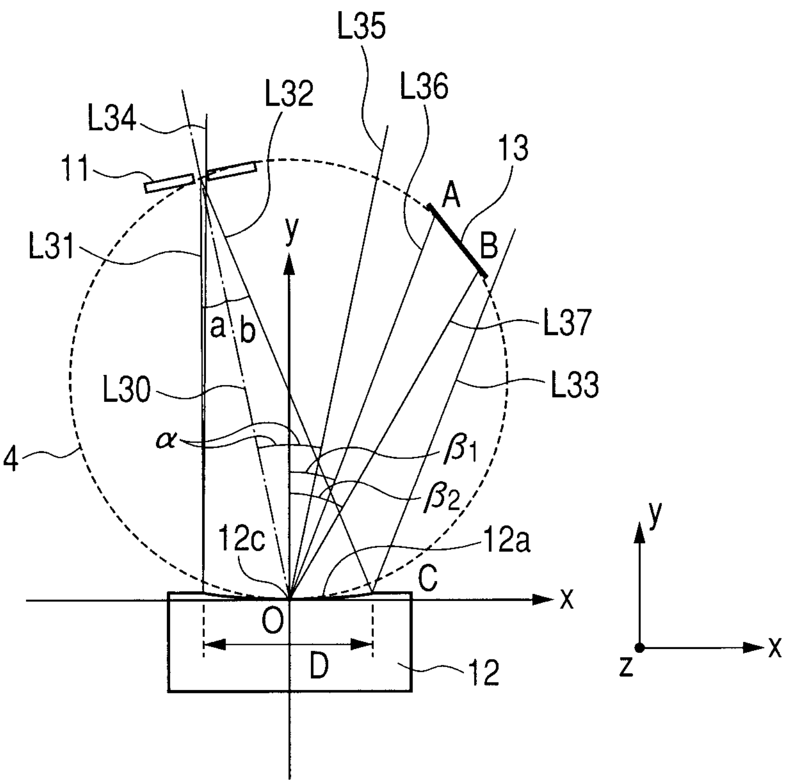

L35
L36
L34
L32
13
11
A
B
y
L31
a
b
L37
L30
L33
α
β1
14
β2
y
12c
12a
C
x
O
x
D
12
z

FIG. 4

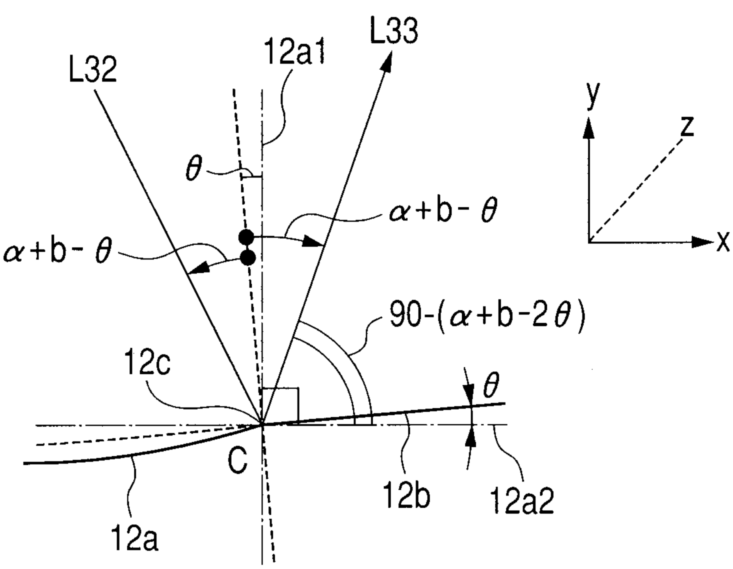

L33
L32
12a1
y
z
θ
α+b- θ
x
α+b- θ
90-(α+b-2θ)
12c
θ
C
12b
12a2
12a

FIG. 5


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TRANSMITTANCE
0
15
30
45
60
75
90
INCIDENT ANGLE

FIG. 6

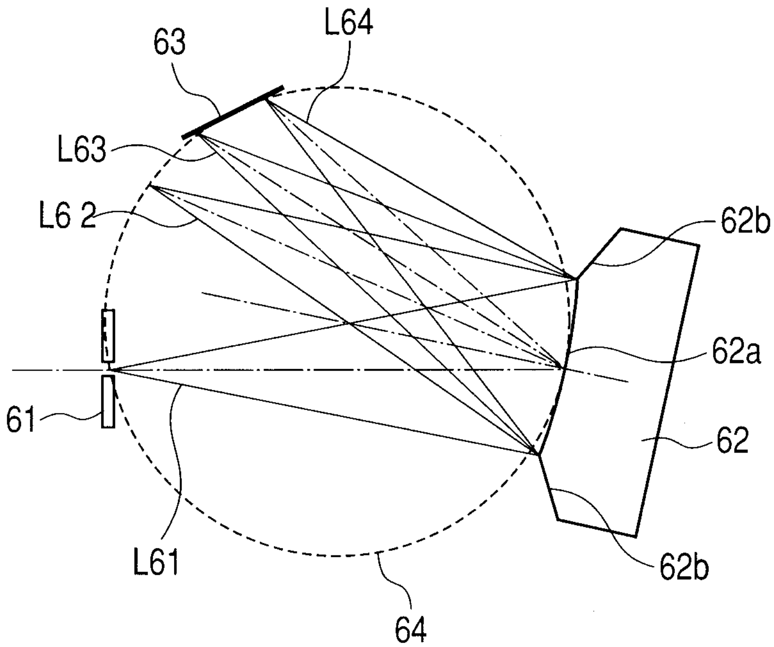

63
L64
L63
L6 2
62b
62a
61
62
L61
62b
64

FIG. 7

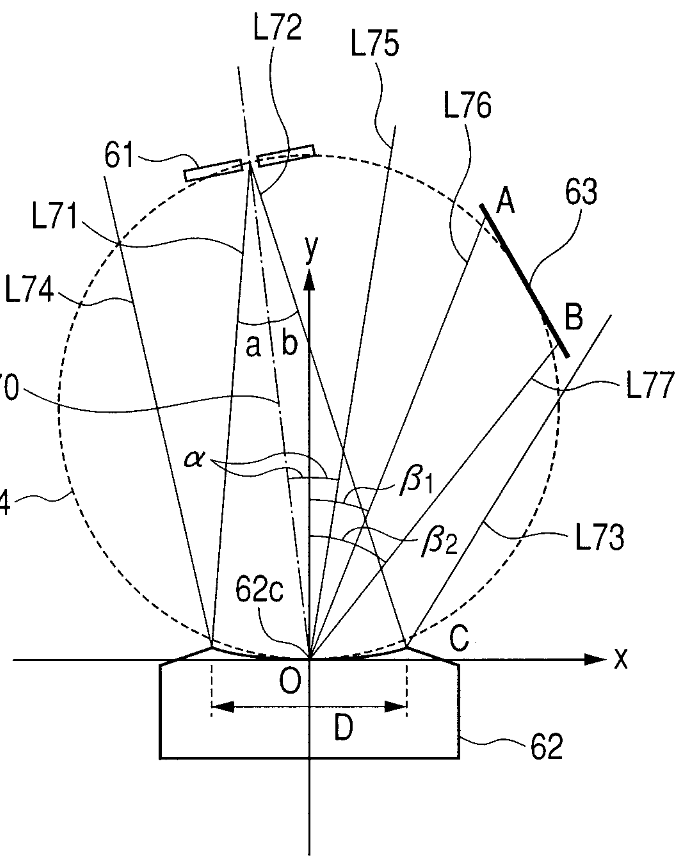

L72
L75
L76
61
63
A
L71
y
L74
B
a
b
L70
L77
α
β1
64
β2
L73
62c
C
x
O
D
62

FIG. 8

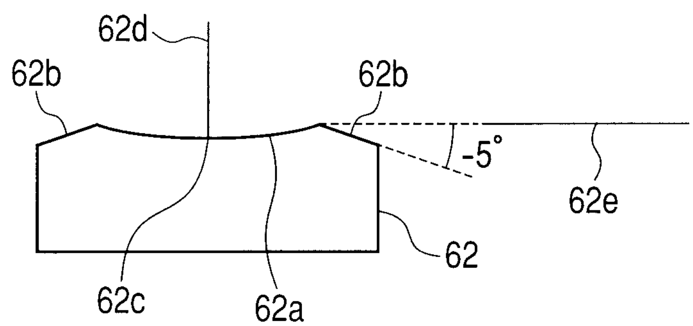
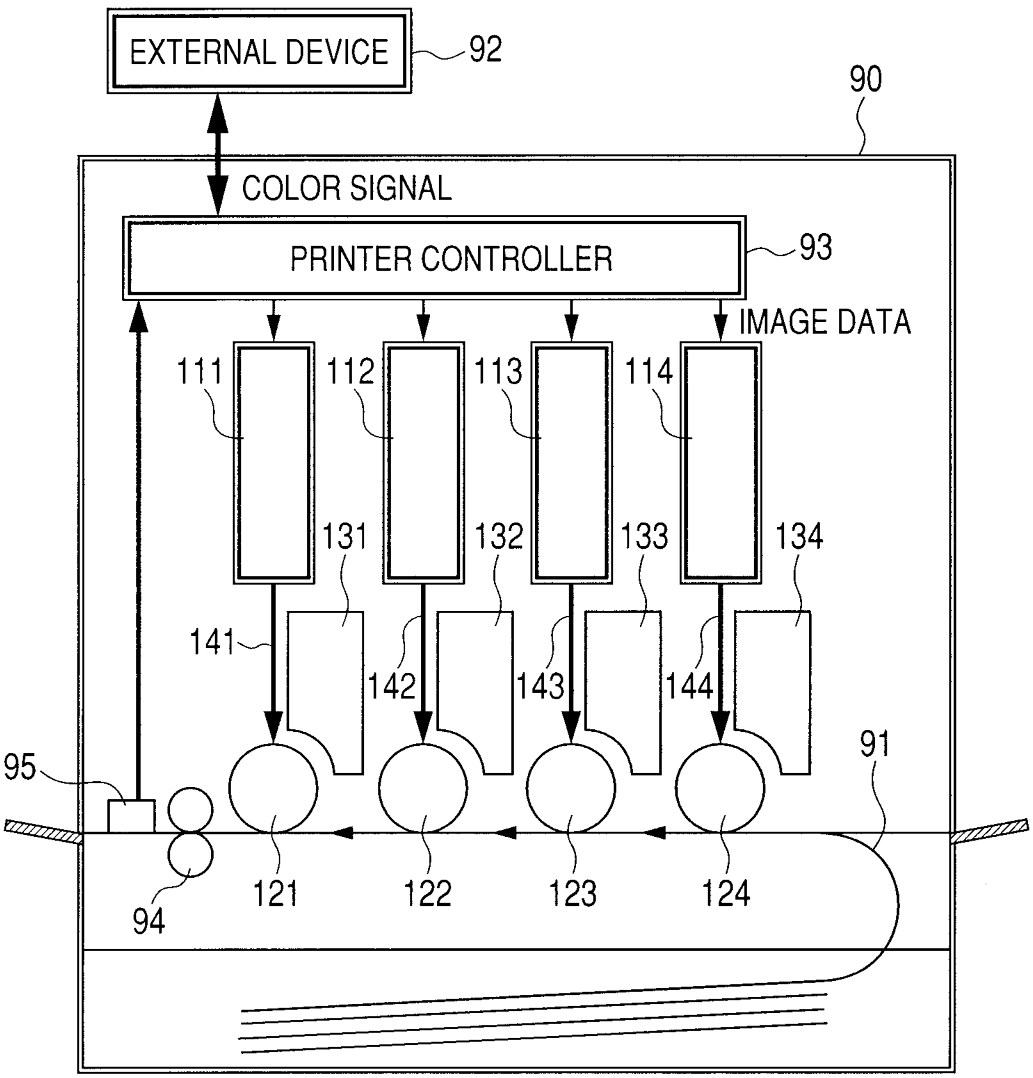

62d
62b
62b
-5°
62e
62
62c
62a

FIG. 9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92
90
COLOR SIGNAL
PRINTER CONTROLLER
93
IMAGE DATA
111
112
113
114
131
132
133
134
141
142
143
144
95
91
94
121
122
123
124

SPECTROMETER AND IMAGE FORMING APPARATUS HAVING THE SAME

BACKGROUND OF THE INVENTION

The present invention relates to a spectrometer and an image forming apparatus having the spectrometer, and more particularly, to a spectrometer including an aperture stop, a diffraction element, and a light detection unit, which are disposed on a circumference of a Rowland circle, and being suitable to detect light having an arbitrary wavelength and an image forming apparatus having the spectrometer.

DESCRIPTION OF THE RELATED ART

Conventionally, there has been a Rowland type spectrometer wherein an incident aperture stop, a reflection type diffraction element, and a light detection unit are disposed on a circumference of a Rowland circle (Japanese Patent Application Laid-Open No. H04-294223). In the Rowland type spectrometer, light reflected on a non-diffraction surface other than a diffraction surface of the diffraction element as stray light (ghost light) may be incident into the light detection unit.

If the stray light reflected on the non-diffraction surface other than the diffraction surface is incident, all output voltages of a plurality of the light detection units disposed in a spectral direction are offset. As a result, in detection of color light of a low-luminosity object, particularly, a black object, the stray light causes a detection error. In the related art, there has been disclosed an optical apparatus where occurrence of the stray light is suppressed (Japanese Patent Application Laid-Open No. 2008-304385).

In the spectrometer discussed in Japanese Patent Application Laid-Open No. 2008-304385, a light absorption layer is disposed in an area where the diffracted light diffracted by the diffraction surface passes through, so that the stray light is absorbed and the occurrence of the stray light is suppressed. As a method for preventing the stray light from being incident into the light detection unit, there is a method in which an aperture stop of limiting a light beam that is incident into the diffraction element is disposed so that light is not incident into any area other than the diffraction surface. In addition, there is a method where a size of the diffraction element is designed to be sufficiently increased, so that light does not collide on any surface other than the diffraction surface. However, if the method for providing the light absorption layer, the method for disposing the aperture stop, and the method for increasing the size of the diffraction surface so as to prevent the stray light are used, the configuration of the spectrometer is complicated.

SUMMARY OF THE INVENTION

The present invention provides a spectrometer capable of effectively suppressing stray light that is reflected from a surface other than a diffraction surface from being incident into a light detection unit and capable of detecting spectral light from the diffraction surface at a high accuracy.

One aspect of the present invention is a spectrometer having a concave reflection type diffraction element which spectrally diffracts incident light beam, wherein, among surfaces other than a diffraction surface of the diffraction element, non-diffraction surfaces which are located outside the diffraction surface at the same side as the diffraction surface are a glossy surface, the spectrometer comprises a light detection unit which is located at an imaging position of a first-order diffracted light diffracted by the diffraction element to receive the first-order diffracted light, and the light detection unit is disposed inside optical paths of light beams regularly reflected on the non-diffraction surfaces outside the diffraction surface.

According to the present invention, it is possible to implement a spectrometer capable of effectively suppressing stray light that is reflected from a surface other than a diffraction surface from being incident into a light detection unit and capable of detecting spectral light from the diffraction surface at a high accuracy.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross-sectional view illustrating a spectrometer according to a first embodiment of the present invention as viewed in a spectral direction.

FIG. **2** is a view for explaining a relationship between a diffraction angle and a grating pitch of a diffraction grating.

FIG. **3** is a view for explaining a locating site of a light detection unit of FIG. **1**.

FIG. **4** is a view for explaining an angle of a light ray L**33** reflected on a surface **12***b* with respect to the surface **12***b* other than a diffraction surface **12***a* of FIG. **3**.

FIG. **5** is a view illustrating a transmittance with respect to an incident angle in Fresnel reflection.

FIG. **6** is a schematic cross-sectional view illustrating a spectrometer according to a second embodiment of the present invention as viewed in a spectral direction.

FIG. **7** is a view for explaining a locating site of a light detection unit **63** of FIG. **6**.

FIG. **8** is a view illustrating a shape of a cross section of a diffraction element **62** of FIG. **6**.

FIG. **9** is a diagrammatic view illustrating main components in a configuration of an image forming apparatus using a spectrometer, according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. A spectrometer according to the present invention includes a concave reflection type diffraction element **12** and an incident aperture stop **11** that guides light from an object to the diffraction element **12**. Among surfaces other than the diffraction surface **12***a* of the diffraction element **12**, non-diffraction surfaces **12***b* which are disposed at two sides of a diffraction direction of a diffraction surface **12***a* at the same side as the diffraction surface **12***a* are constructed with a glossy surface. A light detection unit **13** that receives a first-order diffracted light is disposed at a position corresponding to an imaging position of the first-order diffracted light that is reflected by the diffraction element **12**. The light detection unit **13** is disposed inside optical paths of light beams reflected by the non-diffraction surfaces **12***b* of the two sides and outside an optical path of a zeroth-order diffracted light from the diffraction surface **12***a*. In addition, the incident aperture stop **11**, the diffraction surface **12***a*, and the light detection unit **13** are disposed on a circumference of a concentric cycle (Rowland circle) **14**.

First Embodiment

Now, a spectrometer according to a first embodiment of the present invention is described with reference to FIGS. **1** to **5**.

FIG. **1** is a schematic cross-sectional view illustrating the spectrometer according to the first embodiment of the present invention as viewed in a spectral direction. FIG. **2** is a view for explaining a relationship between a diffraction angle and a grating pitch of the diffraction element **12** of FIG. **1**. FIG. **3** is a view for explaining a locating site of a light detection unit (sensor) **13** of FIG. **1**. FIG. **4** is a view for explaining an angle of a light ray L**33** reflected on a surface **12***b* with respect to a surface (non-diffraction surface) **12***b* other than a diffraction surface **12***a* of the diffraction element **12**. In FIG. **4**, an angle between a surface **12***a***2** perpendicular to a normal direction (y direction) of a surface vertex **12***c* of the diffraction surface **12***a* and the surface **12***b* other than the diffraction surface **12***a* is θ. FIG. **5** is a view illustrating a transmittance with respect to an incident angle in Fresnel reflection. In the figures, the incident aperture stop **11** that is disposed on the circumference of the Rowland circle **14** limits passing of light reflected or dispersed by an object (not illustrated). The concave reflection type diffraction element **11** has a diffraction surface **12***a*. In the diffraction surface **12***a*, the shape of a base surface is anamorphic, and a diffraction grating (grating), of which grating grooves are formed in an equal pitch, is inscribed.

In the embodiment, the surfaces **12***b* other than the diffraction surface **12***a*, which are disposed at two sides of a diffraction direction of the diffraction surface **12***a* at the same side as the diffraction surface **12***a*, have no curvature. For example, the surfaces **12***b* are configured to be planar surfaces. An angle θ between the surface **12***a***2** perpendicular the normal direction **12***a***1** of the surface vertex **12***c* of the diffraction surface **12***a* and the surface **12***b* other than the diffraction surface **12***a* is θ=0°. The surface **12***b* is a glossy surface which is formed by performing a buffing or glossing finishing process (mirror reflection). In addition, the diffraction element **12** is made from a resin. However, the material of the diffraction element **12** is not limited to a resin, but a high-reflectance material such as a metal may be used. In order to increase the reflectance of the diffraction surface **12***a* of the diffraction element **12**, a reflection film may be formed on the diffraction surface **12***a*. Therefore, a sufficient reflected light amount can be obtained, so that detection accuracy can be easily increased. The reflectance of the surface **12***b* is lower than that of the diffraction surface **12***a*.

The light detection unit **13** is disposed on the circumference of the Rowland circle **14**. The light detection unit **13** includes, for example, light detection devices such as CMOS sensors or photodiodes. The light detection unit **13** is configured to be a line sensor where the light detection devices are arrayed in a row in the spectral direction of the spectral light of the diffraction element **12**. The light detection unit **13** may be configured to be an area sensor where the light detection devices are two-dimensionally arrayed. Due to this configuration, the detection signals can be recognized more accurately. The light detection unit **13** is disposed inside the optical paths of the light beams regularly reflected by the non-diffraction surfaces **12***b* that are disposed at outer sides of the diffraction surface **12***a*. The incident aperture stop **11**, the diffraction element **12**, and the light detection unit **13** are disposed on the circumference of the Rowland circle **14**, so that the light diffracted by the diffraction element **12** can be detected by the light detection unit **13**.

An incident light ray L**11** is reflected on an object and passes through the incident aperture stop **11**. A zeroth-order diffracted light (light ray) L**12** is reflected on the diffraction surface **12***a*. A first-order diffracted light L**13** has the shortest wavelength that is detected by the light detection unit **13**. In the embodiment, the first-order diffracted light L**13** has a wavelength of 380 nm. A first-order diffracted light L**14** has the longest wavelength that is detected by the light detection unit **13**. In the embodiment, the first-order diffracted light L**14** has a wavelength of 730 nm. A reference axis (y axis) **21** corresponds to a normal line of the surface vertex **12***c* of the base surface (diffraction surface) **12***a*. An incident light ray L**21** is incident into the diffraction surface **12***a*. An angle −α between the reference axis **21** and the incident light ray L**21** is an incident angle. A light ray L**22** is a zeroth-order diffracted light. An angle α between the reference axis **21** and the zeroth-order diffracted light L**22** is a reflection angle. A light ray L**23** is a first-order diffracted light (first-order light) having a wavelength λ_1. An angle β_1 between the reference axis **21** and the first-order light L**23** is a diffraction angle. A light ray L**24** is a first-order diffracted light (first-order light) having a wavelength λ_2. An angle β_2 between the reference axis **21** and the first-order light L**24** is a diffraction angle. The incident angle α and the diffraction angle β are expressed by the following Equations.

$$\sin\alpha+\sin\beta_i=Nm\lambda_i \tag{1}$$

$$N=1/d \tag{2}$$

Herein, N denotes the number of grating grooves per unit length of the diffraction surface **12***a*; m denotes a diffraction order; λ denotes a wavelength; i denotes a subscript; and d denotes a grating pitch of the diffraction surface **12***a*. A light ray L**30** is a principal ray of a light beam that passes through the incident aperture stop **11**. The principal ray L**30** is incident into the surface vertex **12***c* of the diffraction surface **12***a*. In the figure, an angle between the y axis and the principal ray L**30** is an incident angle α. Among the light rays that pass through the incident aperture stop **11**, a light ray (marginal light ray) L**31** is incident into a negative side (x<0) of the surface **12***b* other than the diffraction surface **12***a*. The angle between the principal ray L**30** and the marginal light ray L**31** is a. Among the light rays that pass through the incident aperture stop **11**, a marginal light ray L**32** is incident into a positive side (x>0) of the surface **12***b* other than the diffraction surface **12***a*. The angle between the principal ray L**30** and the marginal light ray L**32** is b.

A light ray L**33** is the light ray that is closest to the diffraction surface **12***a* among the light rays that are reflected on the positive side of the surface **12***b* other than the diffraction surface **12***a*. A light ray L**34** is the light ray that is closest to the diffraction surface **12***a* among the light rays that are reflected on the negative side of the surface **12***b* other than the diffraction surface **12***a*. A light ray L**35** is a principal ray of a regularly reflected light (zeroth-order diffracted light) reflected by the diffraction surface **12***a*. In the figure, an angle between the y axis and the principal ray L**35** is a reflection angle α. A light ray L**36** is a principal ray of a first-order diffracted light that is obtained by reflecting the light having the shortest wavelength λ_1 (nm), which is detected by the light detection unit **13**, by the diffraction surface **12***a*. In the figure, an angle between the y axis and the principal ray L**36** of the first-order diffracted light is a diffraction angle β_1. A light ray L**37** is a principal ray of a first-order diffracted light that is obtained by reflecting the light having the longest wavelength λ_2 (nm), which is detected by the light detection unit **13**, by the diffraction surface **12***a*. In the figure, an angle between the y axis and the principal ray L**37** of the first-order diffracted light is a diffraction angle β_2. The specifications of the spectrometer and the shape of the diffraction element **12** according the embodiment are listed in Tables 1 and 2.

TABLE 1

(Specifications of Spectrometer)	
spectral range	wavelength of 350 nm to 750 nm
slit width of incident aperture stop	60 μm
detection device (light detection unit)	Si photodiode array
diffraction order m	1
pixel size of detection device	25 × 500 μm
wavelength resolution	3.3 nm

TABLE 2

(Specifications of diffraction element)	
base meridional curvature radius [mm]	17.50
base sagittal curvature radius [mm]	15.45
effective diameter [mm]	7
Grating pitch [μm]	2.52
Grating height [μm]	0.25
blaze angle [°]	5.72
incident angle [°]	12
reflection film	multilayered film of Al base

In the embodiment, the incident aperture stop **11**, the diffraction surface **12***a*, and the light detection unit **13** are disposed on the circumference of the Rowland circle **14**. The light rays that are reflected or dispersed by an object (not illustrated), of which color is to be measured, pass through the incident aperture stop **11** and are incident into the diffraction element **12**. Among the light rays that are incident into the diffraction element **12**, the diffracted light rays reflected by the diffraction surface **12***a* are focused on the circumference of the Rowland circle **14**. Among the light rays that are incident into the diffraction element **12**, the light rays reflected by the surface (non-diffraction surface) **12***b* other than the diffraction surface **12***a* are emitted as the regularly reflected light rays L**35**.

In FIG. **3**, the surface vertex **12***c* of the diffraction surface **12***a* of the diffraction element **12** is set to the origin O(0, 0); the y axis is set to the normal direction (normal direction of the surface) of the diffraction surface **12***a*; and the x axis is set to the direction perpendicular to the y axis. The direction that passes through the origin O and is perpendicular to the x axis and the y axis (that is, perpendicular to the paper surface) is set to the z axis. Hereinafter, the shape in the xy cross section including the normal line of the surface (y axis) is set to the meridional shape, and the shape in the in-plan surface (yz cross section) perpendicular to the xy cross section including the normal line of the surface is set to the sagittal shape. The surface shape (bus shape) of the xy cross section of the base of the diffraction surface **12***a* is expressed by the following Equation (3).

$$y = \frac{x^2/R}{1+\sqrt{1-(1+k)x^2/R^2}} \tag{3}$$

Herein, R denotes a curvature radius of a surface; and the k denotes an eccentricity. When a coefficient of the positive side of the y axis (the upper portion of FIG. **1**) is different from a coefficient of the negative side of the y axis (the lower portion of FIG. **1**), the coefficient of the positive side is marked with a subscript u, and the coefficient of the negative side is marked with a subscript **1**. In addition, the surface shape (sagittal shape) of the yz cross section of the base of the diffraction surface **12***a* is expressed by the following Equation (4).

$$S = \frac{z^2/r'}{1+\sqrt{1-(1+k)z^2/r'^2}} \tag{4}$$

In addition, the r' denotes a curvature radius of the yz cross section. The S denotes the shape of the sagittal line at an arbitrary point on the meridional line. In the diffraction surface **12***a* of the diffraction element **12**, the curvature radius of the meridional line is 17.5 mm, and the curvature radius of the sagittal line is 15.2 mm. In addition, the effective area D is 7 mm. In addition, in the diffraction surface **12***a*, the diffraction grating similar to that of FIG. **2** is formed, and the grating pitch d of the diffraction grating is 2.52 μm, and the blaze angle θ is 5.72°. In this case, the number of grating grooves N is 396.8 grooves/mm. The light that is spectrally reflected by the diffraction element **12** is image-formed (focused) on the light detection unit **13** that is disposed on the circumference of the Rowland circle **14**.

In the embodiment, the light rays detected by the light detection unit **13** are in a wavelength range of 380 to 730 nm. The light rays L**13**, L**23**, and L**36** are the first-order diffracted lights having a wavelength of 380 nm. The light rays L**14**, L**24**, and L**37** are the first-order diffracted lights having a wavelength of 730 nm. By Equations (1) and (2), in the case of m=1, the first-order diffraction angle β_1 for the wavelength of 380 nm is 21.0°, and the first-order diffraction angle β_2 for the wavelength of 730 nm is 29.8°. The light detection unit **13** is disposed in the area where the first-order diffracted light in a wavelength range of 380 nm to 730 nm is received. In addition, in order that unnecessary light is not incident into the light detection unit **13**, the light detection unit **13** needs to be disposed inside the optical paths of the light rays L**33** and L**34** that are reflected by the surfaces **12***b* other than the diffraction surface **12***a*. Since the radius R of the Rowland circle **14** is ½ the meridional curvature radius (=17.5 mm) of the diffraction surface **12***a*, R=8.75 mm. The equation of the Rowland circle **14** is expressed by the following Equation.

$$x^2+(y-R)^2=R^2 \tag{5}$$

In addition, the angles a and b of the marginal light rays L**31** and L**32** with respect to the principal ray L**30** of the light beam that passes through the incident aperture stop **11** are a=11.8° and b=11.3°. The numerical aperture NA of the light beam that is emitted through the incidence aperture stop **11** is NA=0.2. In addition, the principal ray L**30** of the incident light that is incident into the diffraction surface **12***a* is incident at an angle α of 12.0° with respect to the y axis. The coordinate of the intersection point A between the Rowland circle **14** and the first-order diffracted light L**36** having a wavelength of 380 nm is A(5.86, 15.25), and the coordinate of the intersection point B between the Rowland circle **14** and the first-order diffracted light L**37** having a wavelength of 730 nm is B(7.51, 13.12). The angle between the surface (xz surface) **12***a***2** including the perpendicular axis perpendicular to the normal line y of the surface vertex **12***c* and the non-diffraction surface **12***b* is set to θ. In addition, associated parameters are defined as follows.

$$b = \sin^{-1} NA$$

$$\Theta = \tan^{-1}\left(\frac{y_1 - y_2}{x_1 - x_2}\right)$$

$$\begin{cases} x_1 = \dfrac{sR \pm \sqrt{s^2R^2 - (1+s^2)}}{1+s^2} \\ y_1 = sx_1 \end{cases}$$

$$s = \tan(90 - \beta_2)$$

$$\beta_2 = \sin^{-1}(N\lambda_2 - \sin\alpha)$$

$$\begin{cases} x_2 = \dfrac{D}{2} \\ y_2 = 2R - \sqrt{4R^2 - \dfrac{D^2}{4}} \end{cases}$$

Herein, α: incident angle (degree) of the light ray that is incident into the diffraction element.

β_2: first-order diffraction angle (degree) of the light having the longest wavelength that is detected by the light detection unit **13**.

N: number of grating grooves (grooves/mm) of the grating of the diffraction surface **12***a* per unit length (1 mm)

λ_2: longest wavelength (mm) that is detected by the light detection unit **13**.

NA: numerical aperture of the light beam that passes through the incidence slit.

R: radius (mm) of the aforementioned circle.

D: effective area (mm) of the diffraction surface of the diffraction element.

At this time,

$$-90 < \theta < \frac{\Theta + \alpha + b - 90}{2}$$

is satisfied. Herein, the angle Θ is an angle between a straight line connecting B(7.51, 13.12) and C(3.50, 0.0877) and the x axis, in which Θ=72.90. In addition, the angle θ is set so that 90<θ<3.10 is satisfied. In the embodiment, as illustrated in FIG. **4**, the angle θ between the surface **12***a***2** perpendicular to the normal direction **12***a***1** of the surface vertex **12***c* of the diffraction surface **12***a* and the surface **12***b* other than the diffraction surface **12***a* is θ=0°. The equations of straight lines for the light rays L**33** and L**34** that are reflected on the surfaces **12***b* other than the diffraction surface **12***a* are calculated from the angle θ between the surface **12***a***2** perpendicular to the normal direction **12***a***1** of the surface vertex of the diffraction surface **12***a* and the surface **12***b* other than the diffraction surface **12***a* as illustrated in FIG. **4** are expressed by the following Equations.

$$L33: y = \tan(90-\alpha-b+2\theta)x + C_1 \tag{6}$$

$$L34: y = \tan(90-\alpha+a+2\theta)x + C_2 \tag{7}$$

Herein, C_1 and C_2 are constants that are obtained by the following Equations.

$$C_1 = 2R - \sqrt{4R^2 - \frac{D^2}{4}} - \frac{D}{2}\tan(90 - \alpha - b + 2\theta) \tag{8}$$

$$C_2 = 2R - \sqrt{4R^2 - \frac{D^2}{4}} + \frac{D}{2}\tan(90 - \alpha + a + 2\theta) \tag{9}$$

In the embodiment, the constants C_1 and C_2 of Equations (8) and (9) are C_1=−7.77 and C_2=973.54. Since the light detection unit **13** needs to be disposed insides the light rays L**33** and L**34** that are reflected on the surfaces **12***b* other than the diffraction surface **12***a*, the coordinates A and B need to be disposed in the area that satisfies the following Equation.

$$\tan(90-\alpha-b+2\theta)x + C_1 < y < \tan(90-\alpha+a+2\theta)x + C_2 \tag{10}$$

In Equation (10),

$$y \geq \tan(90-\alpha+a+2\theta)x + C_2$$

If the coordinate B is in the above area, the light ray L**33** reflected on the surface **12***b* other than the diffraction surface **12***a* is incident into the light detection unit **13**, so that the accuracy of detection deteriorates. Similarly, if the coordinate A is in the following area,

$$y \leq \tan(90-\alpha-b+2\theta)x + C_1$$

the light ray L**34** reflected on the surface **12***b* other than the diffraction surface **12***a* is incident into the light detection unit **13**, so that the accuracy of detection also deteriorates. In addition, similarly to the light rays reflected on the surface **12***b* other than the diffraction surface **12***a*, since the zeroth-order diffracted light is also a light ray that is not spectrally diffracted, the zeroth-order diffracted light L**35** needs not to be detected by the light detection unit **13**. Therefore, preferably, the light detection unit **13** is disposed inside the diffracted light L**35**, that is, at the position where the zeroth-order diffracted light L**35** is not incident. The Equation of the straight line for the zeroth-order diffracted light L**35** is expressed by the following Equation.

$$L35: y = \tan(90-\alpha)x \tag{11}$$

Therefore, in order that the light detection unit **13** is disposed inside the zeroth-order diffracted light L**35**, it is preferable that the light detection unit **13** is disposed in the area where the following Equation (12) is satisfied.

$$\tan(90-\alpha-b+2\theta)x + C_1 < y < \tan(90-\alpha)x \tag{12}$$

Also in this case, similarly, if the coordinate A is in the following area,

$$y \leq \tan(90-\alpha)x$$

the zeroth-order diffracted light L**35** reflected by the diffraction surface **12***a* is incident into the light detection unit **13**, so that the accuracy of detection deteriorates. In the embodiment, the coordinate of the intersection point A between the Rowland circle **14** and the first-order diffracted light L**36** having a wavelength of 380 nm is A(5.86, 15.25), and the coordinate of the intersection point B between the Rowland circle **14** and the first-order diffracted light L**37** having a wavelength of 730 nm is B(7.55, 13.17). With respect to the coordinate A, the left handed sides of Equations (10) and (12) are as follows.

$$\tan(90-\alpha-b+2\theta)x + C_1 = 5.84$$

The right handed side of Equation (10) is as follows.

$$\tan(90-\alpha+a+2\theta)x + C_2 = 2652.3$$

The right handed side of Equation (12) is as follows.

$$\tan(90-\alpha)x = 27.57$$

Therefore, the coordinate A satisfies Equations (10) and (12). Similarly, with respect to the coordinate B, the left handed sides of Equations (10) and (12) are as follows.

$$\tan(90-\alpha-b+2\theta)x + C_1 = 9.76$$

The right handed side of Equation (10) is as follows.

$$\tan(90-\alpha+a+2\theta)x + C_2 = 3136.4$$

The right handed side of Equation (12) is as follows.

$$\tan(90-\alpha)x = 35.52$$

Therefore, the coordinate B satisfies Equations (10) and (12). Accordingly, the coordinates A and B satisfy Equations (10) and (12); the light detection unit **13** is disposed inside the light rays L**33** and L**34** reflected by the surfaces **12***b* other than the diffraction surface **12***a*; and the light detection unit **13** is disposed inside the zeroth-order diffracted light L**35**. The light detection unit **13** is disposed inside the optical paths of the light beams regularly reflected by the non-diffraction surfaces **12***b* that are disposed at outer sides of the diffraction surface **12***a*. In addition, if the θ is set so that the above condition is satisfied in the direction perpendicular to the spectral direction, since a height of the sensor is 0.5 mm, the light detection unit **13** is disposed inside the optical paths of the light beams reflected by the surfaces **12***b* other than the diffraction surface **12***a*.

The light detection unit **13** is protected by a package such as a cover glass. Therefore, if the angle of the light ray that is incident into the light detection unit **13** is increased, the transmittance is decreased due to the Fresnel reflection, so that the light detection efficiency deteriorates. The change in transmittance according to the incident angle for the cover glass is illustrated in FIG. **5**. Since the components associated with the Fresnel reflection exist, the incident angle is 0°, and the maximum of the transmittance is 96%. At this time, in order to increase the transmittance up to 90% or more, the incident angle of the light ray L**36** having the shortest wavelength that is incident into and detected by the light detection unit **13** needs to be set to 60° or less. It is preferable that, in order to more efficiently detect the light ray, the incident angle is set to 50° or less, more preferably, to 40°; and the transmittance is set to 95% or more.

In the embodiment, the angle between the light detection unit **13** and the light ray L**36** having the shortest wavelength is 29.8°, and the transmittance is 95.6%. More efficiently, in order that the light other than the light that is spectrally reflected by the diffraction element **12** is not allowed to be incident into the light detection unit **13**, the light shielding plate having the aperture that passes through only the necessary first-order diffracted light may be disposed in the peripheral portion in front of the light detection unit **13**. According to the configuration, it is possible to easily perform light detection at high accuracy without reception of the light ray reflected on the surface **12***b* other than the diffraction surface **12***a* by the light detection unit **13**. In addition, the light detection unit **13** is disposed at the position where the zeroth-order light is not received, so that it is possible to easily perform light detection at higher accuracy.

Second Embodiment

Now, a spectrometer according to a second embodiment of the present invention is described with reference to FIGS. **6** to **8**. FIG. **6** is a schematic cross-sectional view illustrating the spectrometer according to the second embodiment of the present invention as viewed in a spectral direction. FIG. **7** is a view for explaining a locating site of a light detection unit **63** of FIG. **6**. FIG. **8** is a view illustrating a shape of a cross section of a diffraction element **62** of FIG. **6**. An angle θ between the surface **62***e* perpendicular to the normal direction **62***d* of the surface vertex **62***c* of the diffraction surface **62***a* and the surface **62***b* other than the diffraction surface **62***a* is θ=−5°. In the figures, an incident aperture stop **61** is configured to limit passing of light reflected or dispersed by an object (not illustrated). The diffraction element **62** has the diffraction surface **62***a*. In the diffraction surface **62***a*, the shape of a base surface is anamorphic, and a diffraction grating, of which grating grooves are formed in an equal pitch, is inscribed.

In the embodiment, the surfaces **62***b* other than the diffraction surface **62***a*, which are disposed at the same side as the diffraction surface **62***a*, have no curvature. The angle θ between the surface **62***e* perpendicular to the normal direction **62***d* of the surface vertex **62***c* of the diffraction surface **62***a* and the surface **62***b* other than the diffraction surface **62***a* is θ=−5°. The surface **62***b* is a glossy surface which is formed by performing a buffing or glossing finishing process (mirror reflection). In addition, the diffraction element **62** is made from a resin. However, the material of the diffraction element **12** is not limited to a resin, but a high-reflectance material such as a metal may be used. In order to increase the reflectance of the diffraction surface **62***a* of the diffraction element **62**, a reflection film may be formed on the diffraction surface **62***a*. Therefore, a sufficient reflected light amount can be obtained, so that detection accuracy can be increased.

The light detection unit **63** includes, for example, light detection devices such as CMOS sensors or photodiodes. The light detection unit **13** is configured to be a line sensor where the light detection devices are arrayed in a row in the spectral direction of the spectral light of the diffraction element **62**. The light detection unit **63** may be configured to be an area sensor where the light detection devices are two-dimensionally arrayed. Due to this configuration, the detection signals can be recognized more accurately. The reference numeral **64** denotes a Rowland circle, and the incident aperture stop **61**, the diffraction element **62**, and the light detection unit **63** are disposed on the circumference of the Rowland circle **64**, so that the light diffracted by the diffraction element **62** can be detected by the light detection unit **63**. An incident light ray L**61** is reflected on an object and passes through the incident aperture stop **61**. A zeroth-order diffracted light (light ray) L**62** is reflected on the diffraction surface **62***a*. A first-order diffracted light L**63** has the shortest wavelength that is detected by the light detection unit **63**. In the embodiment, the first-order diffracted light L**63** has a wavelength of 380 nm.

A first-order diffracted light L**64** has the longest wavelength that is detected by the light detection unit **63**. In the embodiment, the first-order diffracted light L**64** has a wavelength of 730 nm. A light ray L**70** is a principal ray of a light beam that passes through the incident aperture stop **61**. The principal ray L**70** is incident into the surface vertex **62***c* of the diffraction surface **62***a*. Among the light rays that pass through the incident aperture stop **61**, a light ray (marginal light ray) L**71** is incident into a negative side ($x<0$) of the surface **62***b* other than the diffraction surface **62***a*. The angle between the principal ray L**70** and the marginal light ray L**71** is a. Among the light rays that pass through the incident aperture stop **61**, a marginal light ray L**72** is incident into a positive side ($x>0$) of the surface **62***b* other than the diffraction surface **62***a*. The angle between the principal ray L**70** and the marginal light ray L**72** is b. A light ray L**73** is the light ray that is closest to the diffraction surface **62***a* among the light rays that are reflected on the positive side of the surface **62***b* other than the diffraction surface **62***a*.

A light ray L**74** is the light ray that is closest to the diffraction surface **62***a* among the light rays that are reflected on the negative side of the surface **62***b* other than the diffraction surface **62***a*. A light ray L**75** is a principal ray of a reflected light (zeroth-order diffracted light) reflected by the diffraction surface **62***a*. In the figure, an angle between the y axis and the principal ray L**75** is a reflection angle α. A light ray L**76** is a principal ray of a first-order diffracted light that is obtained by reflecting the light having the shortest wavelength λ_1 (nm), which is detected by the light detection unit **63**, by the diffraction surface **62**a. In the figure, an angle between the y axis and the principal ray L**76** of the first-order diffracted light is a diffraction angle β_1. A light ray L**77** is a principal ray of a first-order diffracted light that is obtained by reflecting the light having the longest wavelength λ_2 (nm), which is detected by the light detection unit **63**, by the diffraction surface **62**a. In the figure, an angle between the y axis and the principal ray L**37** of the first-order diffracted light is a diffraction angle β_2 The specifications of the spectrometer and the shape of the diffraction surface **62**a of the diffraction element **62** according the embodiment are listed in Tables 3 and 4.

TABLE 3

(Specifications of Spectrometer)	
spectral range	wavelength of 350 nm to 750 nm
slit width of incident aperture stop	60 μm
detection device (light detection unit)	Si photodiode array
diffraction order m	1
pixel size of detection device	25 × 500 μm
wavelength resolution	3.3 nm

TABLE 4

(Specifications of diffraction element)	
base meridional curvature radius [mm]	17.50
base sagittal curvature radius [mm]	15.45
effective diameter [mm]	7
grating pitch [μm]	1.5
grating height [μm]	0.15
blaze angle [°]	5.72
incident angle [°]	12
reflection film	multilayered film of Al base

In the embodiment, the incident aperture stop **61**, the diffraction surface **62**a, and the light detection unit **63** are disposed on the circumference of the Rowland circle **64**. The light rays that are reflected or dispersed by an object (not illustrated), of which color is to be measured, pass through the incident aperture stop **61** and are incident into the diffraction element **62**. Among the light rays that are incident into the diffraction element **62**, the diffracted light rays reflected by the diffraction surface **62**a are focused on the circumference of the Rowland circle **64**. Among the light rays that are incident into the diffraction element **62**, the light rays reflected by the surface **62**b other than the diffraction surface **62**a are emitted as the regularly-reflected light rays.

In FIG. **7**, the surface vertex **62**c of the diffraction surface **62**a of the diffraction element **62** is set to the origin O(0, 0); the y axis is set to the normal direction of the diffraction surface **62**a; and the x axis is set to the direction perpendicular to the y axis. The direction perpendicular to the x axis and the y axis is set to the z axis. The shape of the diffraction surface **62**a of the diffraction element **62** is the same as that in the first embodiment. In the diffraction surface **62**a of the diffraction element **62**, the curvature radius of the meridional line is 17.5 mm, and the curvature radius of the sagittal line is 15.45 mm. In addition, the effective area D is 7 mm. In addition, in the diffraction surface **62**a, the diffraction grating similar to that of FIG. **2** is formed, and the grating pitch d of the diffraction grating is 1.5 μm, and the blaze angle θ is 5.72°. In this case, the number of grating grooves N is 666.7 grooves/mm. The light that is spectrally reflected by the diffraction element **62** is focused on the light detection unit **63** that is disposed on the circumference of the Rowland circle **64**.

In the embodiment, the light rays detected by the light detection unit **63** are in a wavelength range of 380 to 730 nm. The light rays L**63** and L**76** are the first-order diffracted lights having a wavelength of 380 nm. The light rays L**64** and L**77** are the first-order diffracted lights having a wavelength of 730 nm. By Equation (1) and (2), in the case of m=1, the first-order diffraction angle β_1 for the wavelength of 380 nm is 27.5°, and the first-order diffraction angle β_2 for the wavelength of 730 nm is 44.0°. The light detection unit **63** is disposed in the area where the first-order diffracted light in a wavelength range of 380 nm to 730 nm is received. In addition, in order that unnecessary light is not incident into the light detection unit **63**, the light detection unit **63** needs to be disposed inside the optical paths of the light rays L**73** and L**74** that are reflected by the surfaces **62**b other than the diffraction surface.

Since the radius of the Rowland circle **64** is ½ the curvature radius (=17.5 mm) of the diffraction surface **62**a, R=8.75 mm. The equation of the Rowland circle **64** is expressed by Equation (5). In addition, the angles a and b of the marginal light rays L**71** and L**72** with respect to the principal ray L**70** of the light beam that passes through the incident aperture stop **61** are a=11.8° and b=11.3°. The numerical aperture NA of the light beam that is emitted through the incidence aperture stop **61** is NA=0.2. In addition, the principal ray L**70** of the incident light that is incident into the diffraction surface **62**a is incident at an angle α of 12.0° with respect to the y axis. The coordinate of the intersection point A between the Rowland circle **64** and the first-order diffracted light L**76** having a wavelength of 380 nm is A(7.16, 13.78), and the coordinate of the intersection point A between the Rowland circle **64** and the first-order diffracted light L**77** having a wavelength of 730 nm is B(8.84, 9.16).

The aforementioned Θ is an angle between a straight line connecting B(8.84, 9.16) and C(3.50, 0.0877) and the x axis, in which Θ=59.52. In addition, the angle θ is set so that −90<θ<−3.59 is satisfied. In the embodiment, the angle θ between the surface **62**a perpendicular to the normal direction y of the surface vertex **62**c of the diffraction surface **62**a and the surface **62**b other than the diffraction surface **62**a is θ=−5.0°. The equations of straight lines for the light rays L**73** and L**74** that are reflected on the surfaces **62**b other than the diffraction surface **62**a are calculated from the angle between the surface **62**e perpendicular to the normal direction y of the surface vertex **62**c of the diffraction surface **62**a and the surface **62**b other than the diffraction surface **62**a as illustrated in FIG. **4** are expressed by the following Equations.

$$L73: y=\tan(90-\alpha-b+2\theta)x+C_3 \quad (13)$$

$$L74: y=\tan(90-\alpha+a+2\theta)x+C_4 \quad (14)$$

Herein, C_3 and C_4 are constants that are obtained by the following Equations.

$$C_3 = 2R - \sqrt{4R^2 - \frac{D^2}{4}} - \frac{D}{2}\tan(90 - \alpha - b + 2\theta) \quad (15)$$

$$C_4 = 2R - \sqrt{4R^2 - \frac{D^2}{4}} + \frac{D}{2}\tan(90 - \alpha + a + 2\theta) \quad (16)$$

In the embodiment, the constants C_3 and C_4 of Equations (15) and (16) are C_3=−4.97 and C_4=−19.09. Since the light detection unit **63** needs to be disposed insides the light rays

L**73** and L**74** that are reflected on the surfaces **62**_b_ other than the diffraction surface **62**_a_, the coordinates A and B need to be disposed in the area that satisfies the following Equation.

$$\tan(90-\alpha b+2\theta)x+C_3<y<\tan(90-\alpha+a+2\theta)x+C_4 \quad (17)$$

In Equation (17), if the coordinate B is in the following area,

$$y\geq\tan(90-\alpha+a+2\theta)x+C_4$$

the light ray L**73** reflected on the surface **62**_b_ other than the diffraction surface **62**_a_ is incident into the light detection unit **63**, so that the accuracy of detection deteriorates. Similarly, if the coordinate A is in the following area,

$$y\leq\tan(90-\alpha-b+2\theta)x+C_3$$

the light ray L**74** reflected on the surface **62**_b_ other than the diffraction surface **62**_a_ is incident into the light detection unit **63**, so that the accuracy of detection also deteriorates. The light detection unit **63** is disposed inside the optical paths of the light beams regularly reflected by the non-diffraction surfaces **62**_b_ that are disposed at outer sides of the diffraction surface **62**_a_. In addition, similarly to the light rays reflected on the surface **62**_b_ other than the diffraction surface **62**_a_, since the zeroth-order diffracted light L**75** is also a light ray that is not spectrally diffracted, the zeroth-order diffracted light L**75** needs not to be detected by the light detection unit **63**. Therefore, preferably, the light detection unit **63** is disposed inside the zeroth-order diffracted light L**75**. The Equation of the straight line for the zeroth-order diffracted light L**75** is expressed by the following Equation.

$$L75: y=\tan(90-\alpha)x \quad (18)$$

Therefore, in order that the light detection unit **63** is disposed inside the zeroth-order diffracted light L**75**, it is preferable that the light detection unit **63** is disposed in the area where the following Equation (19) is satisfied.

$$\tan(90-\alpha-b+2\theta)x+C_3<y<\tan(90-\alpha)x \quad (19)$$

Also in this case, similarly,

$$y\leq\tan(90-\alpha)x$$

if the coordinate A is in the above area, the zeroth-order diffracted light L**75** reflected by the diffraction surface **62**_a_ is incident into the light detection unit **63**, so that the accuracy of detection deteriorates. In the embodiment, the coordinate of the intersection point A between the Rowland circle **64** and the first-order diffracted light L**76** having a wavelength of 380 nm is A(7.16, 13.78), and the coordinate of the intersection point B between the Rowland circle **64** and the first-order diffracted light L**77** having a wavelength of 730 nm is B(8.74, 9.06). With respect to the coordinate A, the left handed sides of Equations (17) and (19) are as follows.

$$\tan(90-\alpha-b+2\theta)x+C_3=5.93$$

The right handed side of Equation (17) is as follows.

$$\tan(90-\alpha+a+2\theta)x+C_4=20.70$$

The right handed side of Equation (19) is as follows.

$$\tan(90-\alpha)x=33.69$$

Therefore, the coordinate A satisfies Equations (17) and (19). Similarly, with respect to the coordinate B, the left handed sides of Equations (17) and (19) are as follows.

$$\tan(90-\alpha-b+2\theta)x+C_1=8.34$$

The right handed side of Equation (17) is as follows.

$$\tan(90-\alpha+a+2\theta)x+C_2=29.49$$

The right handed side of Equation (19) is as follows.

$$\tan(90-\alpha)x=41.12$$

Therefore, the coordinate B satisfies Equations (17) and (19). Accordingly, the coordinates A and B satisfy Equations (17) and (19); the light detection unit **63** is disposed inside the light rays L**73** and L**74** reflected by the surfaces **62**_b_ other than the diffraction surface **62**_a_; and the light detection unit **63** is disposed inside the zeroth-order diffracted light L**75**. In addition, if the θ is set so that the above condition is satisfied in the direction perpendicular to the spectral direction, since a height of the sensor is 0.5 mm, the light detection unit **63** is disposed inside the optical paths of the light beams reflected by the surfaces **62**_b_ other than the diffraction surface **62**_a_.

The light detection unit **63** is protected by a package such as a cover glass. Therefore, if the angle of the light ray that is incident into the light detection unit **63** is increased, the transmittance is decreased due to the Fresnel reflection, so that the light detection efficiency deteriorates. The change in transmittance according to the incident angle for the cover glass is illustrated in FIG. **5**. Since the components associated with the Fresnel reflection exist, the incident angle is 0°, and the maximum of the transmittance is 96%. At this time, in order to increase the transmittance up to 94% or more, the incident angle of the light ray L**76** having the shortest wavelength that is incident into and detected by the light detection unit **63** needs to be set to 50° or less. It is preferable that, in order to more efficiently detect the light ray, the incident angle is set to 40° or less; and the transmittance is set to 95% or more.

In the embodiment, the angle between the light detection unit **63** and the light ray L**76** having the shortest wavelength is 44.0°, and the transmittance is 94.8%. As described above, it is possible to easily perform light detection at high accuracy without reception of the light ray reflected on the surface **62**_b_ other than the diffraction surface **62**_a_ by the light detection unit **63**. In addition, the light detection unit **63** is disposed at the position where the zeroth-order light is not received, so that it is possible to easily perform light detection at higher accuracy. According to the above embodiments, components are disposed so that the light rays reflected on the surfaces other than the diffraction surface are not incident into the light detection unit. Therefore, it is possible to implement a spectrometer capable of detecting color light rays at high accuracy with a simple, small-sized configuration.

Third Embodiment

FIG. **9** is a schematic diagrammatic view illustrating main components in a color image forming apparatus (image forming apparatus) using a spectrometer, according to a third embodiment of the present invention. The image forming apparatus according to the embodiment is a tandem type color image forming apparatus where four light scanning units are aligned and image information is recorded on corresponding image bearing members, that is, photosensitive drums. In FIG. **9**, a color image forming apparatus **90**; light scanning units **111**, **112**, **113**, and **114**; the photosensitive drums **121**, **122**, **123**, and **124** as the image bearing members; developing units **131**, **132**, **133**, and **134**; an intermediate transfer belt **91**; and a fixing unit **94** are illustrated.

In FIG. **9**, the color image forming apparatus **90**, R (red), G (green), and B (blue) color signals are input from an external device **92** such as a personal computer. The color signals are converted into C (cyan), M (magenta), Y (yellow), and K (black) image data (dot data) by a printer controller **93** in the color image forming apparatus **90**. The image data are input to the corresponding light scanning units **111**, **112**, **113**, and **114**. Next, light beams **141**, **142**, **143**, and **144** modulated based on each of the image data are emitted from the light scanning units. The photosensitive surfaces of the photosensitive drums **121**, **122**, **123**, and **124** are scanned in the main scanning direction by the light beams.

In the color image forming apparatus according to the embodiment, the four light scanning units (**111**, **112**, **113**, and **114**) are aligned to correspond to the colors of C (cyan), M (magenta), Y (yellow), and K (black). Image signals (image information) are recorded on the photosensitive drums **121**, **122**, **123**, and **124** in a parallel manner, so that a color image can be printed at a high speed.

In the color image forming apparatus according to the embodiment, as described above, through the four light scanning units **111**, **112**, **113**, and **114**, latent images corresponding to the colors are formed on surfaces of the corresponding photosensitive drums **121**, **122**, **123**, and **124** by using the light beams according to each of the image data. Then, the latent images are developed by each of the developing units, and the color images are overlappedly transferred to the intermediate transfer belt. Then, the image is transferred to a recording medium, and the image is formed on the recording medium by the fixing unit.

In the image forming apparatus, a spectrometer **95** for detection chromaticity according to the first or second embodiment is disposed to face an image forming surface of a recording medium after a fixing unit **94** in a transport direction for the recording medium. Herein, the spectrometer **95** having the configuration of the first embodiment is used. The chromaticity of a color patch (patch for chromaticity detection) that is formed and fixed on the recording medium by the image forming apparatus **90** is detected by the spectrometer **95**. The color patch measurement after the fixing on the recording medium is performed in order that the color matching is performed after the change in the chromaticity due to the fixing is considered. The result of detection is transmitted to a printer controller **93**, and the printer controller **93** determines whether the color reproduction of the output monochromic patch is appropriately performed. If a color difference between the chromaticity of the output monochromic patch and the chromaticity instructed by the printer controller **93** is in a predetermined range, the color calibration is finished. If the color difference is not in the predetermined range, the printer controller **93** performs the color calibration based on information of the color difference until the color difference is in the predetermined range. In this manner, the spectrometer **95** according to the present invention is adapted to the image forming apparatus, so that a high-performance color calibration can be performed.

While the invention has been particularly illustrated and described with reference to exemplary embodiments thereof, it will be understood by those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

This application claims the benefit of Japanese Patent Application No. 2009-111747 filed May 1, 2009, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A spectrometer comprising:

a reflection type diffraction element having a diffraction area that diffracts an incident light beam, and a non-diffraction area located outside the diffraction area; and

a light detection unit configured to receive a diffracted light diffracted by the diffraction element,

wherein the diffraction area and the non-diffraction area are integrally composed of a resin,

wherein a reflection ratio of the diffraction area is higher than a reflection ratio of the non-diffraction area,

wherein the light detection unit is disposed inside optical paths of light beams regularly reflected on the non-diffraction area, and

wherein the diffraction area has a base surface that is anamorphic.

2. The spectrometer according to claim **1**, further comprising:

an aperture stop that regulates the incident light beam incident on the diffraction element,

wherein the aperture stop, the diffraction area, and the light detection unit are located on a circumference of the same Rowland circle.

3. The spectrometer according to claim **2**, wherein, when an angle between the non-diffraction area and a tangential surface at a surface vertex of the diffraction area is set θ (degrees), the following condition is satisfied:

$$-90 < \theta < \frac{\Theta + \alpha + b - 90}{2},$$

where:

$$b = \sin^{-1} NA$$

$$\Theta = \tan^{-1}\left(\frac{y_1 - y_2}{x_1 - x_2}\right)$$

$$\begin{cases} x_1 = \dfrac{sR \pm \sqrt{s^2R^2 - (1+s^2)}}{1+s^2} \\ y_1 = sx_1 \end{cases}$$

$$s = \tan(90 - \beta_2)$$

$$\beta_2 = \sin^{-1}(N\lambda_2 - \sin\alpha)$$

$$\begin{cases} x_2 = \dfrac{D}{2} \\ y_2 = 2R - \sqrt{4R^2 - \dfrac{D^2}{4}} \end{cases},$$

and

where:

α: incident angle (degree) of the incident light beam incident on the diffraction element;

β_2: first-order diffraction angle (degree) of the light beam having the longest wavelength that is detected by the light detection unit;

N: number of grating grooves (grooves/mm) of the grating of the diffraction area per unit length (1 mm);

λ_2: longest wavelength (mm) that is detected by the light detection unit;

NA: numerical aperture of the light beam that passes through the aperture stop;

R: radius (mm) of the Rowland circle; and

D: effective area (mm) of the diffraction area of the diffraction element.

4. The spectrometer according to claim **1**, wherein the light detection unit is located outside an optical path of a zero-order diffracted light diffracted by the diffraction area.

5. The spectrometer according to claim **1**, further including a reflection film formed on the diffraction area.

6. The spectrometer according to claim **1**, wherein an incident angle of a light beam having the shortest wavelength among the diffracted light, which is detected by the light detection unit, that is incident into the light detection unit is

50 degrees or less with respect to a normal direction of a light receiving surface of the light detection unit.

7. The spectrometer according to claim **2**, wherein an optical path from an opening of the aperture stop to the diffraction area has no light shielding element.

8. The spectrometer according to claim **1**, further including a light shielding plate disposed in a peripheral portion of the light detection unit.

9. An image forming apparatus comprising:

a fixing unit; and

a spectrometer comprising:

a reflection type diffraction element having a diffraction area that diffracts an incident light beam, and a non-diffraction area located outside the diffraction area; and

a light detection unit configured to receive a diffracted light diffracted by the diffraction element,

wherein the diffraction area and the non-diffraction area are integrally composed of a resin,

wherein a reflection ratio of the diffraction area is higher than a reflection ratio of the non-diffraction area,

wherein the light detection unit is disposed inside optical paths of light beams regularly reflected on the non-diffraction area, and

wherein the diffraction area has a base surface that is anamorphic.

10. The spectrometer according to claim **2**, wherein the aperture stop and the diffraction element are discrete and separate members.

11. The spectrometer according to claim **1**, wherein the wavelength of the incident light beam ranges from 380 nm to 730 nm.

12. A spectrometer comprising:

a reflection type diffraction element having a diffraction area that diffracts an incident light beam, and a non-diffraction area located outside the diffraction area; and

a light detection unit configured to receive a diffracted light diffracted by the diffraction element,

wherein the diffraction area and the non-diffraction area are integrally composed of a resin,

wherein a reflection ratio of the diffraction area is higher than a reflection ratio of the non-diffraction area,

wherein the light detection unit is disposed inside optical paths of light beams regularly reflected on the non-diffraction area, and

wherein the non-diffraction area is constructed with a glossy surface.

13. A spectrometer comprising:

a reflection type diffraction element having a diffraction area that diffracts an incident light beam, and a non-diffraction area located outside the diffraction area; and

a light detection unit configured to receive a diffracted light diffracted by the diffraction element,

wherein the diffraction area and the non-diffraction area are integrally composed of a resin,

wherein a reflection ratio of the diffraction area is higher than a reflection ratio of the non-diffraction area,

wherein the light detection unit is disposed inside optical paths of light beams regularly reflected on the non-diffraction area, and

wherein no optical element is provided on the optical path between the reflection type diffraction element and the light detection unit.

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